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Smoke Abatement by Impaction with Charged Water Droplets

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The use of sprays consisting of electrostatically-charged water droplets to knockdown smoke produced by burning diesel fuel in a chamber was investigated. It was found that a fourfold increase in smoke knockdown capability of water droplets can be achieved by imparting an electrostatic charge to the droplets. Positive and negative charges exhibited similar reductions in knockdown time.

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SMOKE ABATEMENT BY IMPACTION WITH CHARGED WATER DROPLETS

INTRODUCTION

Smoke is a major problem in firefighting, not only because of its potential toxicity, but also because it obscures vision. The problem is particularly severe in shipboard fires where the passageways often become filled with dense, black smoke thereby preventing access to or egress from the fire [1].

In an earlier study, aqueous sprays containing various surfactants were evaluated as a technique for knocking down smoke generated by burning hydrocarbon fuels [2]. Certain surfactants were found to greatly enhance the ability of the water droplets to wet and agglomerate smoke particles. In the present study, electrostatic charging of the droplets is investigated as a method of further improving the ability of water droplets to knockdown smoke.

EXPERIMENTAL PROCEDURE

The smoke knockdown tests were conducted in a quonset type building containing a smoke chamber, 3.05m long, 4.27m wide and 3.05m high at the center, and an observation room (Figure 1). The lower, rectangular-shaped part of the building is of masonry construction, while the upper, semicircular-shaped part is of galvanized iron. The chamber has a volume of 38.3m^3 and is free of leaks. An interior wall separates the chamber from the observation room. A window in this wall fitted with safety glass (0.61 x 0.86m), 1.32m above the floor, connects the two rooms. Opposite the window, 2.82m away, on the smoke side, is a verticle array consisting of three 150-watt projection flood lights, 144mm in diameter. The bottom, middle, and top lights are 0.53, 1.62, and 2.49m above the floor, respectively.

In these experiments, smoke was generated by the free burning of one liter of diesel fuel, grade 2-D [3,4], in a galvanized steel fuel pan 0.30m square and 5cm deep. The fuel pan was placed on a steel table 0.84m above the floor, out of the line of sight of the flood lights as shown in Figure 1.

A Ransburg fogger was used to generate the water droplets. In this device, streams of air at 861 kPa (125 psig) and water at 482 kPa (70 psig) are metered together into a nozzle at flows of 75.5 liters/s and 1.67 cm^3/s, respectively. A hollow-cone spray pattern issues from the nozzle for some 2.5m with an included angle of 70°. Droplets range in diameter from about 25 to 200 μm. The droplets are charged positively or negatively depending on the nozzle charge relative to the voltage ring which surrounds it; they acquire their charge from the nozzle.

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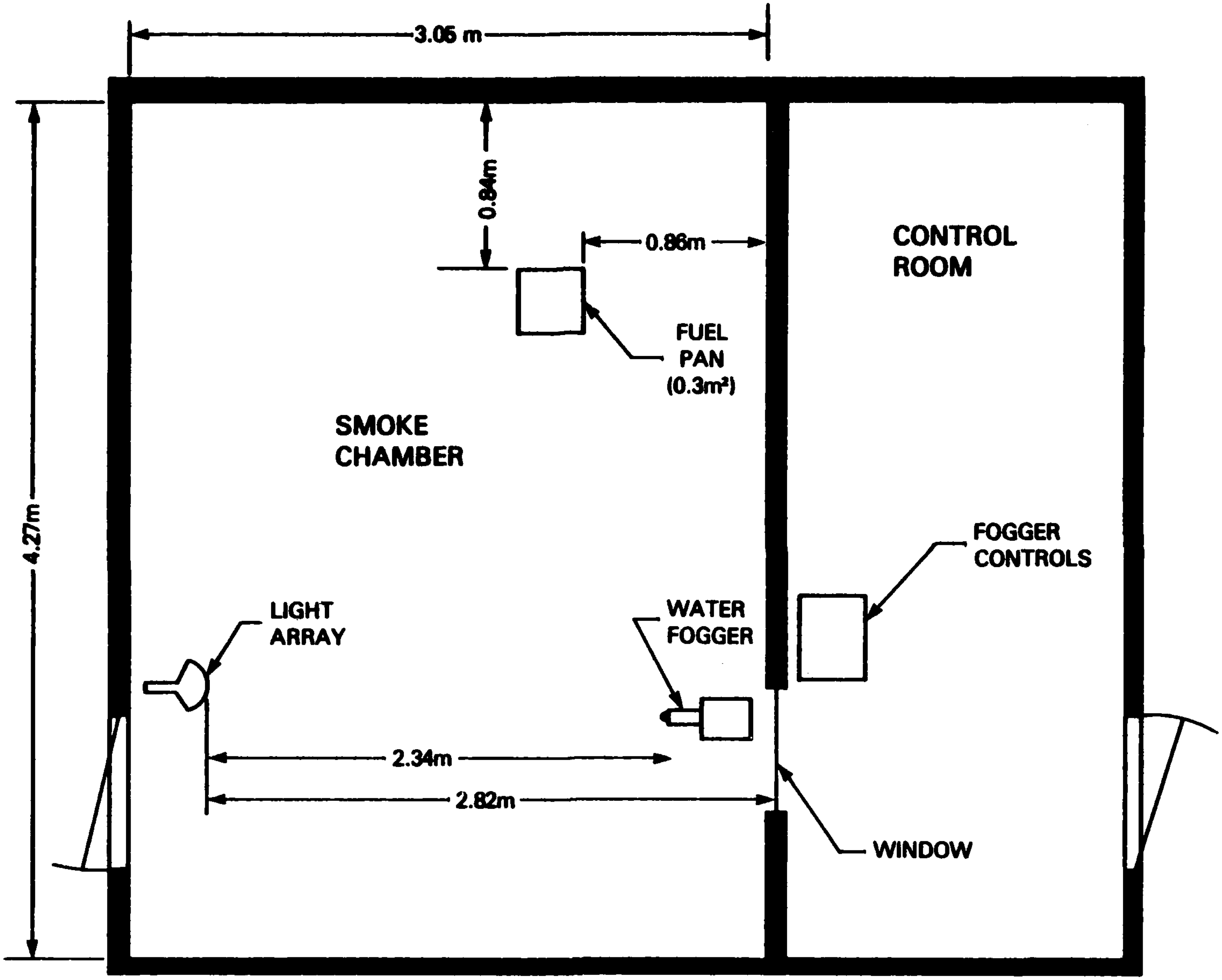

Figure 1 — Plan view of smoke chamber in quonset type building, 3.05m high at the center.

In a typical experiment, one liter of grade D-2 diesel fuel was floated onto water in the fuel pan and ignited. As the fuel burned the chamber filled with smoke. Obscuration of the flood lights was observed from the control room through the connecting window at a distance of 2.82m and times were noted for: (1) ignition of fuel, (2) obscuration of lights by smoke, (3) consumption of fuel, and (4) reappearance of lights.

In the first of a series of runs, agglomeration and gravitational settling times for the smoke were observed in the absence of the water spray. Then the times required to clear the smoke were recorded for the uncharged spray, for the spray charged negatively, and finally for the spray charged positively. To charge the spray, 6.7kV was applied to the ring. In each of the latter three sets, water droplets were projected horizontally in the general direction of the center light. For those runs in which the spray system was used, the system was activated six minutes into the run.

RESULTS AND DISCUSSION

The times for the lights to become obscured after the fire was ignited and to become visible again after the fire burned out (Runs 4,5 and 15), or after the fogger was turned on, are listed in Table I. The mean values and the 95% confidence limits are also given. The confidence limits were determined according to Bauer [5] as recommended for a small number of replications. This statistical procedure uses student t tables and expresses standard deviation as a function of data range. For those runs in which the fogger was used (Runs 6-14 and Run 16), the fogger was turned on six minutes into the run which corresponds to the point at which the fuel was completely consumed.

The results show that in all runs the light array became obscured within 3 minutes after ignition of the fuel with the top light fading from view about 1 minute before the bottom light. If the smoke was allowed to settle by gravity, i.e., without the use of the fogger, it took about 30 minutes for the chamber to clear, with the bottom light becoming visible about 8 minutes before the top.

When the fogger was used but the drops uncharged, it took about 12 minutes to clear the chamber. No significant difference in the viewing times for the top and bottom lights was observed since the fogger cleared the area in front of the lights in a uniform fashion. When the droplets were charged either negatively or positively, the chamber was cleared in about 3 minutes, which was four times as fast as the uncharged droplets.

TABLE I - Obscuration and Visibility Times (Mins)

Run No.	Light Array Obscured* Top	Mid	Bottom	Light Array Visible** Top	Mid	Bottom
			Gravity Settling -- No Fogger			
4	2.0	2.5	3.0	32.0	26.0	25.0
5	1.5	2.0	2.5	32.0	24.0	29.0
15	0.8	1.2	1.6	42.0	33.0	34.0
	Mean: 1.9±0.6			Mean: 30.1±4.9		
			Fogger -- No Charge on Droplets			
12	0.8	1.3	1.8	12.0	12.2	13.0
13	1.0	1.3	1.8	11.0	12.2	10.8
14	0.8	1.3	1.8	11.7	13.5	11.2
	Mean: 1.3±0.3			Mean: 12.0±0.7		
			Fogger -- Negative Charge on Droplets			
7	1.5	1.8	1.8	2.5	1.9	2.2
8	0.8	1.3	1.8	3.5	3.0	3.0
9	0.8	1.0	1.8	2.5	2.5	3.3
10	1.0	1.3	1.8	4.5	3.3	3.3
	Mean: 1.4±0.3			Mean: 3.0±0.5		
			Fogger -- Positive Charge on Droplets			
6	1.5	2.0	2.5	2.3	1.5	2.0
11	1.0	1.3	1.8	3.0	2.5	2.5
16	1.0	1.2	1.5	3.3	2.6	2.6
	Mean: 1.5±0.4			Mean: 2.5±0.5		

* Time required for lights to be obscured after fuel was ignited

** Time required for lights to become visible after fire burned out (Runs 4,5 and 15) or after the Fogger was turned on

CONCLUSIONS

The results of the present study indicate that a fourfold increase in smoke knockdown capability of water droplets can be achieved by imparting an electrostatic charge to the droplets. Previously, it was shown that a similar improvement can be obtained by the addition of a surfactant to water [2]. Therefore, additional studies should be conducted to determine if the combination of surfactant plus electrostatic charging will further enhance the smoke knockdown capability of water droplets.

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